



Using Technology as a means of Verifying the Positioning of Cavity Barriers in a Building Wall Envelope

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CitA BIM Gathering 2019 **Proceedings**

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CitA BIM Gathering Conference 2019 Preface

This is the fourth edition of paper proceedings presented at the CitA BIM Gathering conference. Since our inaugural conference in 2013, the Irish economy and construction sector has continued to recover at a rapid pace. In 2019 there is the looming threat of Brexit, a poor record of productivity in construction and a general shortage of skilled and talented graduates. This recovery has triggered an increased realisation that BIM is important for an efficiently operating industry going forward.

The papers presented in these proceedings cover a variety of BIM related topics but collectively have a common theme that BIM can Deliver Better Project Outcomes for Irish Construction.

It is encouraging to see a number of papers that are addressing public sector BIM adoption in Ireland. The Construction Sector Group, with the support of the Department of Public Expenditure and Reform (DPER), have recently commissioned a study on construction productivity in the Irish construction industry. DPER have reported that Ireland has one of the poorest performing construction industries within the 27 European member states and that policy interventions are needed to remedy the problem.

As we approach 2020 it is hoped that the Irish government will look to fund the implementation of the National BIM Council Roadmap for Digital Transition of the Irish Construction Industry, as both industry and government need a structured programme to support the wider adoption of BIM on Irish construction projects.

CitA was delighted with the support we received in bringing the Gathering to Galway city in 2019 and hope to continue this focus on regional reach in its planning of the BIM Gathering in 2021.

I would like to thank all of the participating partners, the scientific committee, the organisation committee, the authors, the speakers, the sponsors and most importantly the CitA events team for their fantastic efforts in delivering another high quality event that will be remembered fondly by all those that attended.



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CitA BIM Gathering **Proceedings**

BIM and Lean Procurement Practices

Using Technology as a means of Verifying the Positioning of Cavity Barriers in a Building Wall Envelope

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Abstract - Addressing the well publicised build quality issues within the construction sector is arguably the greatest challenge facing the industry at present. Issues can arise from a lack of proper on-site inspection leading to inadequate workmanship detailing along with substitution of materials from those originally specified at the technical design stage. Whilst such deviances from original technical design intent can have negative consequences in relation to building performance, such as a reduction in thermal and acoustic properties, this pales into insignificance compared to potential life safety issues. One of the most obvious threats to life safety within a building is fire, and the identified areas of workmanship, detailing and inspection are critically important in ensuring sound details are constructed, none more so than in ventilated façades. Ventilating façade systems have become popular over recent years due to the range of colours, styles and profiles which allow most aesthetical intentions to be realised. This, coupled with the general robust performance and ease of construction, means they are a popular choice for contemporary buildings and in retrofitting projects. However, with ventilated façades, like with any envelope, there is the potential for passive fire protection issues, with the performance in a fire dependent on the workmanship detailing, especially with regards to cavity barriers, and the materials used during the construction. This becomes critical in light of reported issues relating to fire safety inspection. This paper focuses on verifying the positioning of cavity barriers in ventilated façades. The research firstly triangulates the stated issues relating to quality via a focus group discussion with industry professionals, with a focus on fire safety, before the potential for a technological solution is presented in the form of a clash detection analysis using captured point cloud data of in-progress construction work linked to a project BIM. The conclusion suggests that technological interventions have the potential to assist inspectors in more robustly verifying positioning in relation to fire safety, whilst acknowledging that this is only one component of a verification workflow which must also include material and detail verification.

Keywords - Digital Technology, Verification, Inspection

I HISTORICAL PRECEDENT & INDUSTRY SHIFT

Knaack *et al.* [1] outline that the wall and façade makeups we are familiar with today are a result of a lengthy process of development. Traditional methods of building enclosure for walls made use of materials such as brick and stone. However, the use of such materials along with solid or cavity wall construction methods were not realistic for buildings of larger scale due to the sheer amount of materials needed to achieve adequate wall depths for structural stability. This resulted in the need for alternative construction techniques for taller buildings, leading to the development of more advanced façade systems. Depending on individual ideology, the façade can either be viewed upon in practical terms, as a necessity to achieve the performance requirements in a building, or as an art form [2] [3].

With a growing recognition of the importance of building performance [4], a demand for increased efficiencies in façade design has occurred [5], with the purpose of a façade primarily for architectural expression becoming discredited. This has possibly been influenced by the emergence of the Architectural Technology profession with professionals providing a more analytical approach to the design process governing material selection, detailing and technical performance, coinciding with regulatory requirements which place an increased focus on aspects such as acoustics, thermal performance and life safety. Modern façade systems offer a way for older buildings to upgrade their overall performance in line with regulatory requirements via retrofitting. This is becoming a necessity considering the assertion that 97% of the European Union building stock requires upgrading [6]. A 2003 study discussing the UK perspective

highlighted issues with tower blocks built during the early 1960s such as thermal bridging and water ingress resulting from poor quality materials, workmanship, supervision and inadequate services. It was foreseen that such issues could potentially be remedied by “adopting ‘high tech’ components involving composite cladding methods” [7]. One of the most common systems in both new and retrofit situations is the ventilated rainscreen, comprising of an outer cladding material, behind which is an air gap, insulation and fixings [8] with additional materials such as cavity barriers also placed. With the rise in popularity and comprehensive use of such systems, proper construction is essential in not only ensuring the performance improvements are realised, but more importantly, in ensuring that life safety is not compromised.

II LIFE SAFETY & VENTILATED RAINSCREEN SYSTEMS

The greatest life safety consideration in buildings is undoubtedly fire. Despite periodic revision of the legislation there persists a continued reliance on visual inspection to ensure compliance is achieved on-site. This is not only logistically difficult on large projects, but brings with it the risk of human error. Concerns have been raised in relation to compartmentation, especially in concealed spaces and in terms of inspection of fire barriers [9]. Ventilated rainscreen systems introduce concealed spaces and thus passive fire protection must be considered. Ventilated rainscreen systems have become popular over recent years due to the range of colours, styles and profiles which allow most aesthetical intentions to be realised. This, coupled with the general robust performance and ease of construction, means they are a popular choice for contemporary buildings and in retrofitting projects. However, like with any wall envelope, there is the potential for issues in relation to passive fire protection, with the performance in a fire dependent on workmanship detailing, especially with regards to cavity barriers, and the materials used during the construction.

Ventilated rainscreen systems rely on passive fire protection measures, the first stage of which is “*slowing down the development of a fire and its rapid spread by using construction materials with low flammability and combustibility*” [10]. The building regulations throughout the UK require cavity barriers to be installed for buildings in all

purpose groups with concealed spaces. Such cavity barriers are required to be placed at regular intervals both vertically and horizontally to provide compartmentation and around openings in the wall envelope. Littlewood *et al.* [9] citing the work of others (Shipp *et al.* 2015; Shipp *et al.* 2016; Littlewood & Smallwood, 2015; Gorse *et al.* 2016) outline that compartmentation can be affected by defects in construction detailing. It has been suggested that key technical details and materials can be changed during construction [11], this could potentially lead to inappropriate construction materials or detail makeups being used for fire-protection. Littlewood *et al.* [9] conducted a study with Fire and Rescue Service professionals which found the vast majority of respondents experienced difficulty in assessing the effectiveness of building compartmentation as part of fire risk audits and assessments. The study stated:

“When asked about inspection of fire and smoke barriers in concealed spaces in buildings, 25% of respondents never inspect concealed spaces while 63% inspect the concealed spaces. Among all the respondents who inspect the concealed spaces, the majority rely on limited non-intrusive visual inspection alone...”

The serious implications of less than optimum passive fire protection measures have been demonstrated in cases such as the Knowlesy Heights fire, where defects or the absence of fire barriers contributed to fire spread [12]. More recent investigations have illustrated the need for a focus to be placed on on-site cavity barrier detailing due to the potential for installation issues [13, 14, 15 & 16]. The Hackitt Report made reference to the regulatory system and the need for change to better ensure fire safety: “*The current regulatory system for ensuring fire safety in high-rise and complex buildings is not fit for purpose*”. The same report also called for a “*golden thread*” to ensure “*the original design intent, and any subsequent changes or refurbishment, are recorded and properly reviewed, along with regular reviews of overall building integrity*”. Such a process would help ensure that there would not be, what Littlewood *et al.* [9] describes as, “*inadequate transfer of construction details from Architect/Design team to Building Contractor’s site operative.*”

In aiming to realise this ambition the potential for technological solutions must be investigated. The current digital transformation within the construction sector means there is potential for technology to be applied in helping to devise a more rigorous inspection and verification process. Project Verify, a research project at Ulster University, is investigating the potential for data collection technologies to potentially link to the BIM workflow for the purposes of closing the identified quality gap. It is focusing on ventilated rainscreen details and aiming to use data collection technologies for the purposes of verification of on-site materials, their positioning and aspects of workmanship detailing. The work to date would suggest that no one technology will serve as a panacea, but rather, a combined technological approach, aligning with the suggestions of O’Kane *et al.* [17] may be required. The alignment of the findings of [9] with the work being undertaken at Ulster University would suggest that there is merit in evaluating if a technological workflow could be applied to ensure a more robust approach to inspection of passive fire protection measures.

III THE CHANGING CONSTRUCTION SITE ENVIRONMENT

The realisation of the BIM mandate which was published in the 2011 Government Construction Strategy [18] has contributed to an increased use of digital technologies on construction sites. It is routine to now witness individuals with tablet devices on-site, using these to interrogate models and commission installed components. Indeed, things are moving at pace, with technological advances facilitating faster site inductions and allowing for safer working environments. A project which is embracing such technological change is the new build Southern Regional College (SRC) Campus located in Armagh, Northern Ireland (Fig 1).



Fig. 1: Project Building Information Model for the SRC Campus

The main contractor on the SRC Campus project, Felix O’Hare & Co Ltd, have been proactive in their use of technology to both inform decision making and the overall build progress. They have recognised that specific roles, such as a Head of Digital Construction and Site BIM Implementation Coordinator, are required to assist with technology driven culture change and implementation, with the latter a type of soft landing for site personnel. They

have implemented the use of SignOnSite [19] to apply technologically driven management of safety and have worked closely with their design team in the development of the project BIM, using this to manage on site operations in conjunction with the Dalux suite of applications [20]. This has seen numerous benefits, some of which include assigning digital snag lists to sub-contractors who can instantly



access these via their mobile device along with the most up to date model ensuring unbroken information flow and enhancing coordination. Other technological implementations include the use of total stations by the main contractor to aid setting out, using points taken from the federated model. Regular laser scans have also been taken to check accuracy and to benchmark progress against the project BIM (Fig. 2).

Fig. 2: Use of technology on the SRC Campus

In addition, virtual and augmented reality tools are being utilized to aid the end user understanding and indeed enhancing the clarity and understanding for the main contracting team. The use of laser scanning is now becoming common practice amongst larger contractors to validate the presence and correct location of major construction elements such as beams and columns.

A review of literature would suggest a lack of focus on the use of this technology as a means of checking positioning of vital minor components on site, minor in terms of scale as opposed to importance, which make up intricate and critical construction details and have a profound impact on life safety. This paper aims to triangulate the issues

relating to construction quality issues before the potential for a technological solution is presented in the form of a clash detection analysis using captured point cloud data of in-progress construction work linked to a project BIM.

IV RESEARCH METHODOLOGY & DATA ANALYSIS

This mixed method study [21] is an example of real-world research, identifying and focusing on a specific issue within the construction sector with the aim of finding a potential solution. This aligns with the definition of Sekaran & Bougie (2013) cited in [22] who define research in the real world as being a “*systematic and organized effort to investigate a specific problem that needs a solution*”.

A qualitative approach will be used in the form of a focus group [23], to gain insights from industry professionals on matters relating to fire safety and the potential for technological interventions relating to inspection. The focus group participants were purposively selected due to their knowledge and experience in the area under investigation. Using a focus group allows participants to “*explore and clarify their views in ways that would be less easily accessible in a one to one interview*” [24]. NVivo software was used to assist with the analysis of the focus group transcripts [25]. In addition, data will be gathered and analysed by trialing the use of a remote sensing technology, aligned to a project BIM, for the purposes of determining positioning of as-constructed cavity barriers. The Toulmin model of argument [26] will be employed to analyse the solution presented. Ethical approval was sought and obtained for the study.

V PROFESSIONAL INSIGHT & ANALYSIS

A focus group discussion took place with five industry professionals, all building control surveyors, and focused on aspects relating to passive fire protection and inspection processes. It should be noted that only the summarised key findings are presented in this paper. The dialogue led to agreement in relation to visual inspection not being conducive to ensuring correct location of components and specification of materials. A strong emphasis was placed on building control surveyors only seeing a ‘snapshot’ in time and cannot be relied upon to inspect every element of the building fabric. Participants referred to situations where materials are not specified by designers, such as in performance based specifications. It was highlighted that in some instances it is left up to the contractor to decide on material selection during the project. Hence, such decisions are potentially taken by individuals not suitably qualified or who are unaware of the potential ramifications. It was stated that whilst material substitution was not uncommon, it was less frequent on large projects. There was a

feeling that contractors sometimes see it as their duty to cut costs and, in certain scenarios, will deviate from approved plans if they find a ‘similar’ product at a reduced cost. The conversations suggested that material verification can be an issue in certain circumstances, especially when numerous components go into a complex detail makeup. Sometimes checking the integrity of the detail in relation to product defects or gaps is the only viable means of inspection given time and other constraints.

It was highlighted that third party accreditation of cavity barriers on external wall facades was being offered by some distributors where companies visually inspect sub-contractors installation and provide certification. Additional discussions suggested that on-site workmanship can be problematic with tradesmen under minimal supervision and sometimes unaware as to why specific components, critical to detail integrity and life safety, require exact installation as per manufacturers specification. The need for a competent clerk of works, someone providing non-biased inspections and not accountable to the contractor, was outlined. However, there was a realisation that this may only gain traction if it became a legislative requirement due to incurred costs.

Conversations focused on the regulatory system being unable to guarantee that a building being inspected is safe in all aspects of construction and the realisation that designers sometimes ‘use’ the plan assessment process as a checklist as opposed to designing for compliance. It was made evident that the potential for a technological approach to assist with verification of on-site detailing would be welcomed, but it was unclear as to what would be required to drive such a process due to the constant focus on reducing costs. A transcript of the full focus group dialogue was entered into NVivo and a word cloud generated of the frequently occurring words in the data (Fig. 3).



Fig. 3: A word cloud of frequently occurring words generated by NVivo

VI MATERIAL POSITIONING

The review of literature highlighted the critical nature of cavity barriers in containing fire spread in addition to issues with their inspection. This, coupled with the potential benefit of a technological means of assisting inspection, led to the following aims for the stage two case study. To develop a technological workflow to:

- (1) Automate the process of detecting the presence of cavity barriers during on-site operations
- (2) Capture the exact positioning of the cavity barrier prior to envelope closure, assisting with robust asset information model development

The remote sensing technology selected for investigation was laser scanning with the new build SRC project used as a hypothetical case study. It should be noted that this study was not inspecting the veracity of the work on this project. Primary data was collected by visiting the site and conducting a laser scan using the Leica RTC360 3D Laser Scanner [27] on the front façade (Fig. 4).



Fig. 4: Front façade of the SRC Project under construction

The captured scan was firstly imported into Autodesk Recap and registered before being exported into Revit. The quality of the front elevation scan was ideal for this project, with a close up view demonstrating the ability to identify the cavity barrier positioning (Fig. 5).



Fig. 5: Horizontal cavity barrier displayed in Recap

For the purpose of the experiment, the proposed cavity barrier positions were identified from the two-dimensional technical drawings and added to the Revit model as components (Fig. 6). This allowed for the point cloud and project BIM to be overlaid to check positioning (Fig. 7).

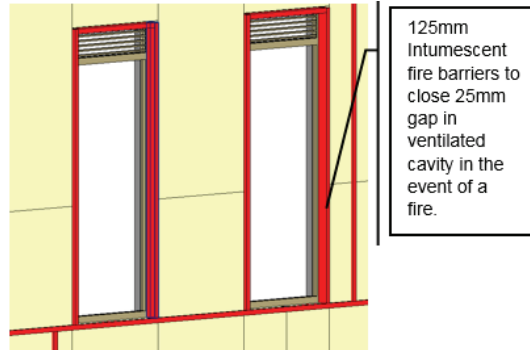


Fig. 6: Revit Model



Fig. 7: Imported Point Cloud

This not only allowed for checking if any cavity barriers were missing, but provided a means to record exact positioning of cavity barriers for robust asset information capture. For this study only a visual comparison was made between the Point Cloud data and the Revit model as seen in Fig 8. However, it is evident that positioning of fire barriers can be confirmed via this process, with the potential for automation via the use of clash detection.

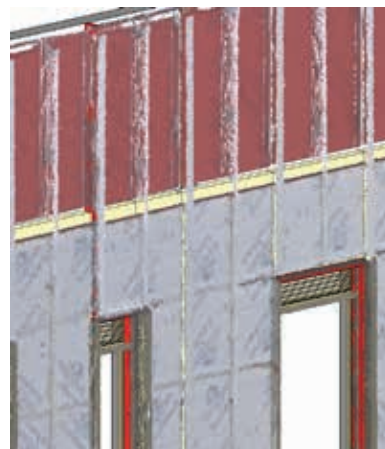


Fig. 8: Imported Point Cloud & Revit Model

VII DISCUSSION & CONCLUSION

The claim of inadequacies relating to visual inspection of passive fire protection for life safety has been corroborated by the review of literature and the findings of the focus group. The findings suggest that the current means of visual inspection, whether it be from a regulatory body or third-party accreditor, is not adequate for ensuring the in-built performance of fire safety measures. Therefore, there is a need for increased supervision on construction sites or others means which can verify the veracity on constructed details.

Such failings have serious implications, as, in the event of a fire, missing, damaged or use of the incorrect type of cavity barrier, not flagged by inspectors, can undermine the passive fire strategy leading to the spread of smoke and flame outside of the designed compartment. The building regulations and inspection processes are in place to help ensure life safety in built assets, with guidance provided on both active and passive fire measures. It is important that adequate regulation is followed by robust inspection processes to ensure on-site compliance and protect building occupants. Littlewood *et al.* [9] called for non-intrusive and non-destructive test methods for assessing passive fire protection. A testing method as identified in this study could seamlessly align with and contribute to the BIM process for the purposes of validating and verifying Asset Information Models for facilities management purposes. Whilst inspection to verify correct placement of cavity barriers alone will not act as a panacea, it is a key component in the overall strategy. The 'threat' alone of using such technological processes may also be sufficient to discourage the practice of altering or changing details on site as reported in [17]. With the fast paced technological advancements evident in the construction sector it could be an ideal time to promote and utilize digital technologies and processes to help improve construction quality.

Construction failings could in part be due to procurement practices which place less of an emphasis on quality, certainly in comparison to time and cost, Bowen *et al.* [28] citing Bennett and Grice, 1990. This is evident from the focus group findings presented in this study which highlighted the possibility of contractors reducing construction costs without giving holistic consideration to key construction details potentially impacting on life safety. Broadly it could be an indication that the construction sector fails to recognise itself as a service industry delivering products to end users. As outlined by Hackitt (2017), "*The focus must shift from achieving lowest cost to providing buildings which are safe and fit for people to live in for years to come.*"

Whilst the potential for using a remote sensing technology to verify the position of cavity barriers in a project BIM has been identified, this is only one

part of the equation as the verification procedure against a project BIM is reliant upon the model being developed to a level of detail in which components such as fire barriers are modelled. Presently the level of model development varies greatly in projects. Future research projects which investigate this area and the extent to which such components are currently modelled and the level of detail stipulated in Employer Information Requirement documents would be valuable. Other practicalities would need to be considered such as the most appropriate method of capturing data on wall envelopes under construction but concealed behind protective sheeting on-site.

This paper could be considered as an early stage scoping study, hence the recommendations presented should be considered in this context. However, it highlights an area worthy of further investigation. The findings suggest there is a need for on-site verification of critical details from a life safety perspective, with technological approaches potentially playing a significant part in future implementation. It is evident that there is a lack of communication between designers, contractors and inspectors. Whilst technological intervention won't necessarily fix the communication void, the use of remote sensing technologies linked to a project BIM has shown potential in verifying positioning of critical components. The findings from the focus group would suggest that real change requires legislation to enforce a new regulatory system which embraces digital approaches and aligns with the BIM Level 2 process. This is required to ensure important life safety aspects of buildings and other performance related details are constructed as per designers' intentions.

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